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C. F. WATSON

THE SUITABILITY OF VARIOUS
ALLOYS FOR SOCKETING WIRE
ROPE ALSO A FEW TESTS ON
WIRE ROPE

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**THE SUITABILITY OF VARIOUS ALLOYS FOR SOCKETING WIRE ROPE
ALSO A FEW TESTS ON WIRE ROPE**

by

HIRAM EUGENE GINGRICH

and

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**A Thesis Submitted for the Degree of
BACHELOR OF SCIENCE
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UNIVERSITY OF WISCONSIN

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Table of Contents.

Introduction - Statement of Problem - Page 1

Part I. Investigation of Socketing Alloys

A. General Information

(a) Requisites of Socketing Alloy	-----	4
(b) Study of Alloys	-----	5
(c) Effect of different metals on strength and melting point of mixture	-----	5

B. Alloy mixing and testing

(a) Methods of preparation	-----	6
(b) Difficulties	-----	10
(c) Methods of testing	-----	11
(d) Difficulties of testing	-----	12
(e) Determination of melting point	-----	13
(f) Table of results	-----	13a
(g) Alloys chosen to test in sockets	-----	14

C. Socketing cables ----- 14

D. Action of sockets in test ----- 16

E. Conclusions on tests ----- 18

Part II Testing Cables.

A. Objects of test. ----- 19

B. Strength of Individual wires.

(a) Apparatus and method	-----	19
(b) Difficulties	-----	22
(c) Table of results	-----	22

C. Cable Tests.

(a) Apparatus	-----	23
(b) Difficulties	-----	23
(c) General results	-----	29
(d) Curves	-----	33
(e) Cable Efficiencies	-----	39

D. Conclusions and General Observations ----- 40.

Tests on Suitability of Various Alloys for Socketing Wire Rope.

Introduction.

Whenever attempts have been made to run tests on wire rope, it has always been found that the first problem confronting the investigator was the one of securing the rope in the testing machine in such a manner as to make the specimen break near its middle and not in, or close to, the devices used for holding it.

The ordinary bolt clips, which hold the cable merely by the pressure produced by the tightening of bolts, will invariably slip before the full strength of the cable has been developed. Bending the cable around large drums is also very unsatisfactory, particularly with steel rope. The bending strains set up, in combination with the tensile stresses, cause failure at the bend before the full tensile strength had been developed in the straight part of the rope. The method of fraying, or unraveling the end of the rope, and placing this end in a conical socket, and then pouring a suitable babbitt around the wires is the most generally recommended way of fastening a socket to a rope. Obviously the last statement of the method is too general. Some manufacturers recommend that the wire be frayed, then bent back to form loops and then pulled into the socket and

babbitted. These men place their faith on the socketing or wedging tendencies of the loops of wires and very little on the babbitt. However, a few ropes, so socketed, were tested in the laboratory of the University of Wisconsin, and all failed in the sockets. The failure was such as to show that the socketing did not distribute the load evenly in the strands.

Other manufactures advocate fraying the cables, but not bending the wires. They then drive a conical steel plug down into the center of the rope, wedging it as much as a specimen is wedged in an ordinary testing machine. Next they pour babbitt into the socket to aid in holding the wires and plugs in place, and to develop a little more strength. This method, too, gives socket failures when efforts are made to break the rope.

Still other manufacturers recommend the fraying of the rope and the use of the conical socket as in the preceding two methods. They go farther, however, and thoroughly clean the rope end by boiling it in caustic potash, and then tinning it with zinc chloride. Then when the babbitt is poured into the socket, a union is brought about between the metal and the wires. This method was recommended by one of the oldest wire rope concerns in the United States. It is essentially the same method recommended by Professor

J. B. Johnson in his "Materials of Construction", with the exception that the frayed ends in the first method are left straight, while Professor Johnson hooked or bent the ends of the wires.

As the conical socket with the wires held in place by means of babbitt is the ordinary commercial form of socket, it was decided to use this method of socketing in preparing cables for the testing machine.

Search for a suitable alloy or babbitt for the socketing medium disclosed the fact that little was known on the subject. Wherever a mixture was mentioned, either the exact proportions were not given, or it was mentioned in such a way as to raise doubts as to its suitability and consistent performance. Professor Tetmajer, a German investigator, quoted two mixtures, one for hard steel rope and one for iron rope. The Watertown Arsenal reports gave several mixtures, which they reported as having been tried and found satisfactory. Since so little definite information was available, it was decided that the wisest thing to do was to run a series of tests on different alloys and try to find one which would be suitable for the work.

Part I.

Alloy Tests.

The first question which arose was: What are the requisites of a good socketing alloy? Obviously, it must possess considerable strength. The strains set up in the alloy, when in a socket and holding a loaded cable are complex, but must be largely compressive and shearing strains. So the alloy would have to be strong in these two respects and in tension as well. Also the alloy must have a low melting point so that, when poured into the socket, it will not heat the wires of the rope sufficiently to draw their temper. Reports of tests made by the Transvaal Government during an investigation of mines advocate that alloys for socketing cable should have a melting temperature of 500° F. or less, preferably about 350° F. From conferences with various professors in the university, it was decided that the melting point of the alloy could easily be higher than 500° F., for two reasons. First, the annealing temperature of the steel being over 1000° F., it was thought probable that no bad results would come to the wires so long as they were not heated to or above this temperature. Secondly, even if the alloy, were near the annealing temperature of the wires, it is doubtful if they would be brought to this temperature by pouring the metal

around wires, because of the cooling effects of the iron sockets and the conductivity of the wires.

In trying to find an alloy of high strength and low melting point, it was discovered that no data had been published which showed the strength and melting point of the same alloy, except a few double mixtures. Much interesting information was at hand concerning the strength of various mixtures and also the melting points of others, but not the strengths and melting points of the same one.

In order to make a series of mixtures for test purposes it was first necessary to study the properties of the different soft metals when used in mixtures.

It was found that the copper-zinc alloys were remarkably strong, but of too high melting point.

Copper-aluminum likewise makes a strong alloy, but has a high melting point, especially in the proportions which produce the greatest strength.

Zinc-aluminum makes a strong alloy and has a fairly low melting point for certain proportions. The melting point of the whole series in fact is below the annealing temperature of the steel in the cables.

Tin and lead have low melting points, but their alloys are weak, the best having a tensile strength of only 11000 pounds per square inch.

Antimony when alloyed with other metals helps reduce the melting point and also gives it the property of expanding on cooling. It was thought this would be a desirable property in a socketing alloy.

Bismuth adds nothing to the desirability of an alloy except to materially lower its melting point, which property cadmium has also.

Tin hardens and strengthens an alloy and also decreases its elongation.

Lead and cadmium add to the fluidity of the molten alloy. Fluidity was greatly to be desired in the socketing metal, as it would have to flow well around all the wires in the socket.

Copper added much to the strength and ductility of an alloy.

Having these properties in mind twenty-eight mixtures, including one previously used at the Watertown Arsenal, were decided upon and those showing high strengths and low melting points were to be actually tried out in sockets. These mixtures were proportioned by weight.

The volume of the mould was determined approximately, allowance being made for probable waste in pouring, and the weight of this quantity of water computed. Then multiplying this value by the desired percentage and the

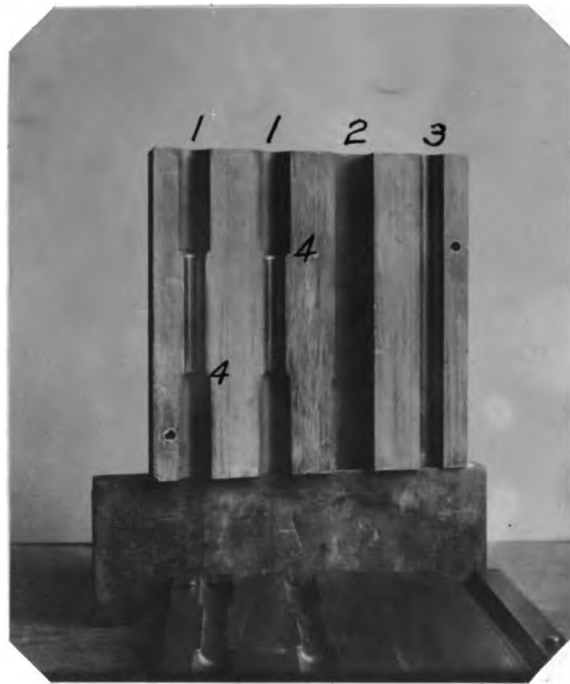
specific gravity of the metal in question, the proper weight was found which was then weighed out to the nearest one quarter ounce on the balance scales. No chemical analysis was made after the specimens were tested to check the resulting mixtures and while the percentages no doubt changed some in melting, due to the volatilizing of some of the different ingredients, still this variation ought not to be very large, as precautions were taken to keep it down.

A gas furnace oven (Plate No. I) was used for melting the metals. This consisted of a small iron oven, lined with fire brick and having a door at one end. Heat was furnished by a hot gas flame. City gas, carburated by means of a mechanical blower, was used. The metals were melted in graphite crucibles, which were handled by means of suitable tongs. A wide range of temperatures could be obtained by varying the amounts of air or gas.

The mold (Plate No. II) used in casting the specimens was made of cast iron. At one pouring it was possible to cast up two tension specimens, and compression and shear specimens, each long enough to make two tests upon. The mold was made in two pieces and was held together by means of clamps when specimens were being cast. The accompanying photograph (Plate No. II) shows the shapes of the

PLATE NO. 1*Furnace**1- Gas Valve**2-Air Valve*

PLATE NO.2



Mold

*1-Tension Specimen 2 - Shear Specimen
3-Compression Specimen 4- Shoulder*

specimens.

No difficulty of any importance was experienced in melting the alloys. They were covered with powdered charcoal to prevent oxidation and the furnace flame was kept regulated so as to make a non-oxidizing flame. The aluminum compounds were rather refractory, and took some time to melt, but otherwise gave no trouble in the furnace.

In pouring, it was found that the powdered charcoal had a marked tendency to flow along with the metal into the molds. After several rather ineffectual attempts this was prevented by placing a notched stick in the crucible, and having the notch in the stick come opposite the lip of the crucible. A hole was thus formed through which only the molten alloy flowed.

Some^{difficulty} was experienced due to the shape of the mold for tension specimens. As can be seen from the photograph of the mold, the tension specimen has a small middle section and larger ends. The specimens were cast with the molds in an upright position. Due to the sudden contraction at the junction of the large and small section, eddies were evidently set up by the rising fluid metal, and caught there slag and formed blow holes. Many of the tension specimens broke at this lower shoulder and the fracture invariably showed either blow holes or slag or both. The aluminum

alloys, with the exception of the one with the least percent of aluminum broke the lower shoulder off in cooling in the mold. This was due to the strains set up by the excessive shrinking of aluminum. It is suggested that this shoulder be made much longer if more tests of this nature are to be made, or a straight specimen be cast which can be tested that way, or with a smaller machined section.

In casting the specimens their behavior was carefully watched. The lead-tin alloys all poured easily and gave good specimens. The aluminum-zinc alloys did not pour so well. Evidently the surface tension of this mixture is high, for it always poured a large stream, while the lead-tin mixtures poured a small one.

The tests for strength were performed in the conventional manner. Tension specimens were held in the usual wedge grips, while the shear tests were made with the Johnson shear tool in daily use in the testing laboratory in the University of Wisconsin. The section of the shear specimen was one half of a square inch, so that, as the test makes a double shear fracture, the scale reading was the shearing strength in pounds per square inch. Compression specimens were cut off in a lathe so that the compression surfaces were parallel. All the alloys flowed so in compression that no definite ultimate strength

could be found. Therefore, after several trials, it was decided to use as the ultimate load that load which would produce a deformation of twenty- per cent in the specimen. This was very close to the real ultimate strength, for at just about this point there was a decided falling off in the rate at which the specimen took load. On account of the jagged nature of the fracture of most of the tension specimens it was not possible to take measurements for computing the percent of elongation. The fracture was so jagged that it could not be put back so as to close within several hundredths of an inch, so that accurate measurements were rendered impossible. For this same reason the per cent of reduction of area could not be obtained, the fracture being so irregular as to make a close measurement of the diameter impossible. There was no noticable elastic limit in any of the alloys.

After the specimens had been tested, the broken pieces were remelted and the melting points measured by means of a thermo-couple, the temperatures obtained being measured by the deflections of a milli-voltmeter. The thermo-couple was a union of nickle and a nickle-chromium alloy and was reasonably reliable up to temperatures of about 1000° F.

An iron tube, made of a piece of iron pipe, plugged at one end, was placed in the molten metal, and the thermo-

couple placed in the iron tube. The whole mass of metal was then stirred until the deflection recorded by the millivoltmeter had gone up and commenced coming down. This showed that the tube had become as hot as the metal and that its heat was changing with that of the metal. The metal was now carefully watched and the millivoltmeter^{reading} taken as soon as the first signs of solidification appeared. This was taken as the freezing-point and that was assumed to be the same as the melting point.

It was noticed that when the iron tube was put into the aluminum-zinc alloys, the alloy attacked the iron and took off quite a bit of the outer part of the pipe. This immediately raised a question as to its effect on the wires in the cable. Evidently it would have a good bond strength.

The following table shows in a condensed form the results of the tests on the alloys. The composition of the alloy, its strength in tension, shear and compression are given and also its melting point, as determined by the method just described.

From a study of the table it appeared that alloy No. 2 was the logical choice when the requisites of a socketing alloy were taken as a basis for decision. It had, with the exception of the aluminum-zinc compounds, the highest strength and a low melting point. So No. 2 was chosen as

TABLE No. 1

Table showing Composition, Strength and Melting Point of Alloys.

No.	Composition in %								Average Ultimate Strength in $\frac{\text{lb}}{\text{in}^2}$			Melting Point $^{\circ}\text{F}$	Remarks
	Pb	Sn	Sb	Bi	Cu	Al	Zn	Cd	Tension	Compression	Shear		
0	80	5	15						8560	12975*	6650	510	In tension specimens Nos
18						53	47		24900	57500	27310	953	deformation without signs of cracks. Shear fract. silky.
19						50	50		24750	63200	29425	930	Tension fract. crystalline.
20		40	15	3	2	40			3760	20150*	7000		Poor mix. Acted like cast iron.
21		70		2	3	25			13210	28150	12145	1052	
22		70			10	20			4490	17800	9095	1110	
23		20				70			13550	20900	9655	1140	Very ductile. No necking.
24		70		5	10	15				30250	13810	1220	
25	20	60				20			10150	14350	7275	1010	
26	30	60				10			9080	10850	5570	920	
27						45	45	10	36950	65950	25510	945	Cadmium probably burned out of these two. #27 pulled off ends of tension specimens in mold.
28						58	32	10	33600	64900	27710	1015	
Compression values marked * were obtained by drop of beam. Rest of values obtained by stressing through 20% deformation as explained in text.													

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a good one to use. For purposes of comparison it was thought best to try out more than one alloy in a cable. To try out against No. 2, No. 1 was chosen.

The Aluminum-zinc alloys had created no little comment because of their great strength and comparatively low melting temperatures. Working on the assumption that the melting point of the alloy could be as high as the annealing temperature of the steel, it was decided to try out alloy No. 19. This alloy was composed of equal parts of aluminum and zinc and had the lowest melting point of that series. To socket the other end of the cable alloy No. 6 was chosen. This was a Watertown Arsenal mixture and answered moderately well the requirements of a good socket metal. So four alloys were to be tried out, involving two cables. A very strong, high grade steel cable was selected, it being the strongest of three specimens upon which individual wire tests had already been run. Obviously, if the sockets would hold this one, they would hold weaker ones.

In preparing the cables the first step was cutting off suitable lengths. At points five feet apart on the cable sets of four servings were made. Two of these were about one and one half inches apart with the five foot mark. The others about 11 in. apart with 5 ft. mark as center. The cable was cut by placing it on the anvil of a steam hammer and striking the cutting chisel held on

the cable several sharp blows. The servings, or windings, kept the rope from untwisting, which in hard steel rope, is very hard to prevent. After the cutting, sockets were slipped on the specimen, the serving near the end broken and the ends of the cable frayed out. The sockets used were designed for one and one eighth inch cable, and so easily slipped over the cut ends.

After the wires were all frayed out and straightened, the hemp core down to the serving was removed. The wires were then cleaned, first by dipping in gasoline and then in hot, strong, caustic potash. After the cleaning, the wires were dipped in a solution of zinc chloride. Tinning was accomplished by dipping the prepared end into a pot containing enough of the molten metal to cover the wires as far as necessary. This pot was made of a piece of large pipe covered at one end by a cast iron pipe cap.

When the wires were thoroughly tinned the cable ends were pulled into the sockets, which had been loose in the middle of the cable during the fraying, cleaning and tinning processes. The alloy was then poured in, care being taken to thoroughly fill the socket.

Here it is of interest to note the socket dimensions. These were ordinarily used commercial "loop" sockets designed for one and one eighth inch rope. The cone was

four and one half inches long, and the upper diameter was two and one half inches. Some tests described in the Engineering and Mining Journal for March 7, 1908, page 500, describe a socket for a seven-eighths inch cable as having a small diameter of one inch and opening to four inches in four and one quarter inches. This was reported as holding, but the tests here described would indicate that the socket was unnecessarily large.

Having socketed the cables, the next step was to stress them until either the cables broke or the sockets failed. The load was applied in the big column machine in the laboratory of the University of Wisconsin. Both cables failed by breaking in the middle of the rope and none of the sockets showed any signs whatever of failure. There was a slight slippage, less than one eighth of an inch, but that was only to be expected. After breaking the cables and finding that all four alloys held the rope, the cables were cut off close to the sockets and the mass of alloy and wires drawn out. The appearance of the socketed ends is shown in the accompanying photograph. (Plate No. III)

The fact that all four alloys proved satisfactory was not so gratifying an outcome as might be expected. Had one failed, or all but one failed, the results of the tests would have been more definite. As the matter now stands no absolute conclusions can be drawn. It is

PLATE NO.3*Socketed Ends**1, 2, 6 and 19 - No. of Alloy Used*

hardly possible that the only four alloys that would hold were selected merely by the inspection of the table.

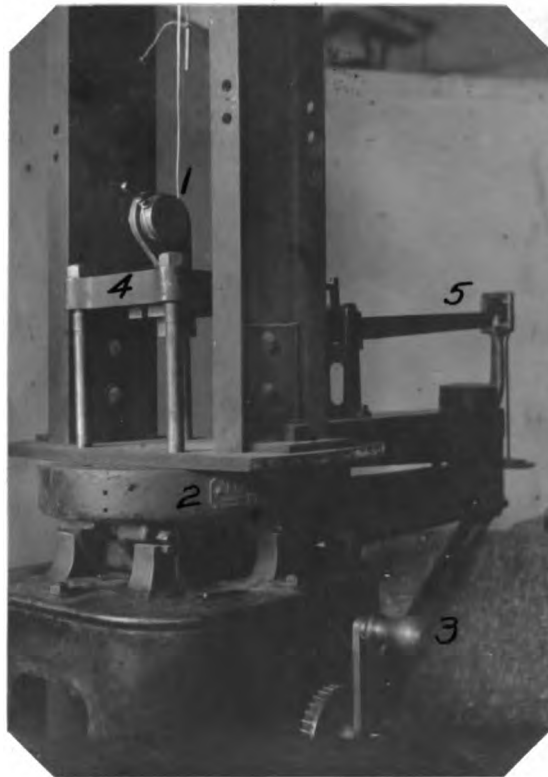
Surely all of the aluminum-zinc alloys would hold, although the ones with the higher aluminum content might have a bad effect on the wire due to their higher melting point. However, it is extremely doubtful if the temperature is high enough for this. Also there is no reason to suppose that the rest of the series, of which No. 1 and No. 2 are a part, would not hold the cable. The question has now become: Is the matter of socketing a wire rope so much a question of proper socketing material as it is one of proper preparation? Is the cleaning and tinning of the wires the important step, and the selection of the alloy secondary?

Having found four alloys to hold the cable, it remained to try out one a little farther. An inspection of the ends showed that alloy No. 6 had made the best end. (See Plate III) So it was chosen to socket two more steel cables of the same grade and one iron cable.

Part II.

A suitable socketing alloy having been found and decided upon, a very interesting field of experiment was opened, namely the determination of the ratio of the cable strength to the aggregate strength of the individual wires making up the cable. This cable efficiency is a very uncertain matter, different experimenters having gotten results varying from 75% to 95%. While the limits of this work would not allow sufficient experimenting to arrive at any final conclusions, still the results are interesting in as much as they may throw some light upon the subject and may show whether or not the socket method successfully distributes the strain in all the strands and wires of the rope.

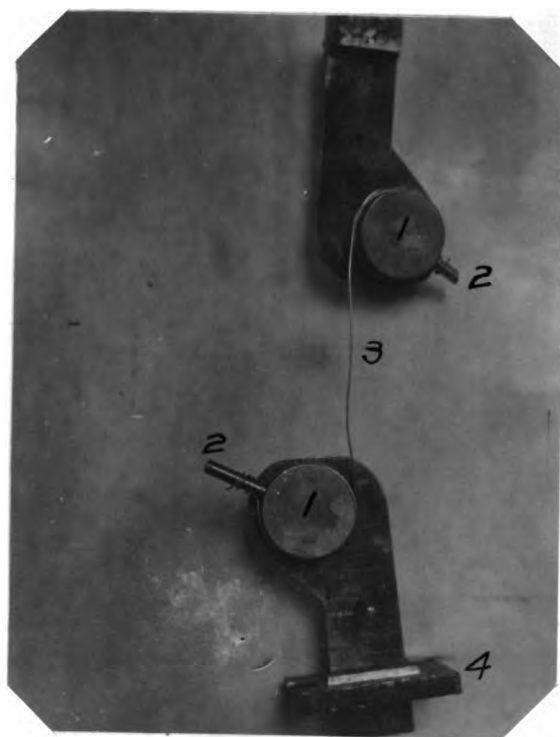
The strength of the individual wires was found by actual test, the wires being placed in a testing machine and pulled to failure, the breaking or ultimate load being noted. The machine and apparatus used for this purpose is shown in Plates No. IV and No. V. The wires were wrapped twice or more around the three inch drum and then snubbed on the pin. The apparatus was then placed in the machine and load
 5 applied slowly, the beam being kept continually balanced, thus giving finally the load at breaking. As the cables were abundantly greased to prevent corrosion, all the wires had to be washed in gasoline before they could be calipered

PLATE NO.4

Wire Testing Machine

*1-Wire Pulling Apparatus 2-Weighing Table
3-Power Crank 4-Movable Head
5-Scale Beam*

PLATE NO. 5

*Wire Pulling Apparatus*

*1-3" Drum 2-Pin or Lug
3-Wire 4-Plate to hold apparatus
 centered in machine.*

and placed in the machine. Eight wires from each cable were tested. In the case of the iron cable these were of the same size but in the various steel cables where the strands were made up of two sizes, four wires of each size were tested. The yield point and ultimate strength were so nearly coincident in the case of the steel cables that only the ultimate was taken. The yield point as determined by the drop of the beam for the iron wires proved of no great importance. It was attempted to determine that the % of the elongation and % reduction of area in all cases, but due to some reason, probably to too small a diameter of drum, the wires without exception, broke upon the first bend, thus making the necessary measurement impossible or at least inaccurate.

Table No. 2 gives the results of the wire tests made and is self explanatory.

Strengths of Various Wire Ropes as Determined by
Individual Wire Tests.

Spec. No.	Diam. of Rope.	Make up.		Diam. of		Strength in lbs.	
		No. of Wires.		Wires.		per sq. inch.	
		Large	Small	Large	Small	Large	Small
6	1 in.	114	---	.067	---	71,900	----
7	1 in.	60	.54	.0845	.0461	222,250	233,970
8	1 in.	78	.36	.0749	.0539	194,700	182,125
9	1 in.	78	.36	.0744	.0553	213,300	225,400

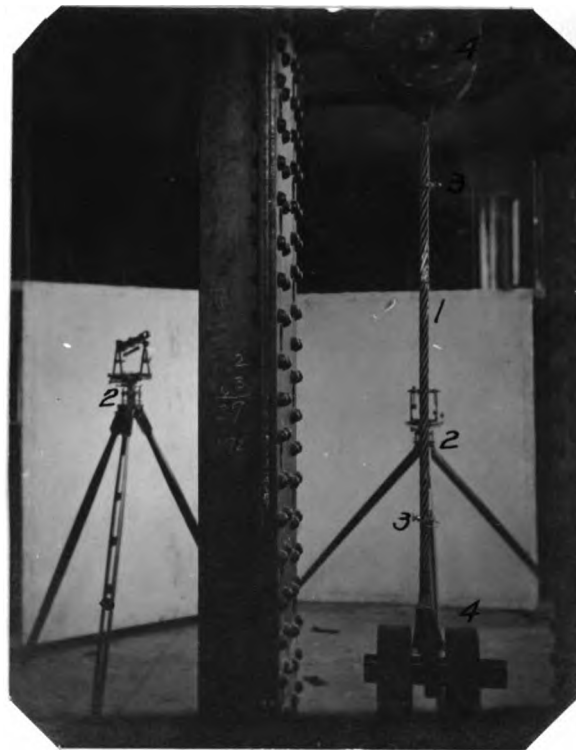
Spec. No.	Net or Metal Area.	Total Aggregate Strength of Wires.
6	.4040 Sq. in.	29,050 lbs.
7	.3970 " "	89,338 "
8	.4258 " "	81,800 "
9	.4271 " "	92,120 "

Note:- Yield point of iron wires = 44,500 lbs.

per square inch.

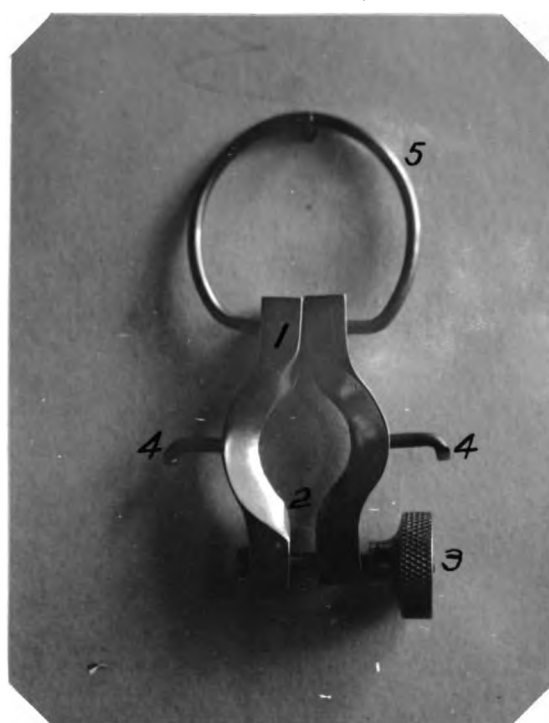
The tests of the cables proper were carried on by placing five foot specimens, socketed as previously explained, in the 600,000 lb. hydraulic testing machine, of the University of Wisconsin. The machine has the top head stationary and the bottom one movable and is operated by an oil pump and so arranged that the power may be used in moving the head in either direction (up or down). The pressure of the oil is measured by gages carefully calibrated so that gage readings may be changed, by simple substitution, into pounds load. When the flat column heads are replaced by the tension heads as shown in Plate No.VI, the machine is ready to receive the specimen.

One real problem in this connection was to find a suitable method for measuring the deformations. The common extensometer method could not be used since as the load is applied, the specimen tends to untwist and each end turns in the opposite direction. The error due to this twist would be considerable when it is remembered that a roller extensometer works on an axle of

PLATE NO.6*General View of Test**1-Cable**2-Transits**3-Scale Holder**4-Tension Heads*

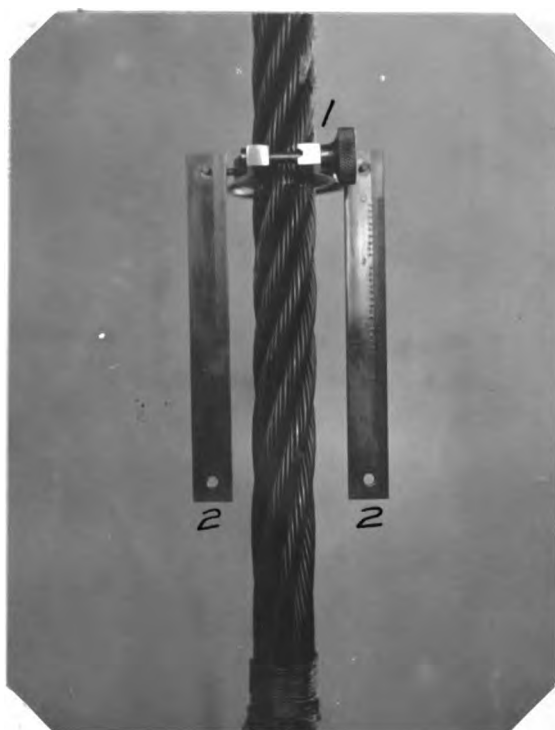
some length, thus making the twist not around a circle one inch in diameter, but about five inches. Another difficulty in this connection was due to the fact that upon stretching, the cable diameter was reduced to such an extent that any ordinary clamp would become loose and slip from its position during the course of the test. This also applied to the extensometer method. To overcome these difficulties the apparatus, shown alone in Plate No. VII, and Plate No. VIII is shown attached to the cable. It consists of two steel collars held together on one side by a spring and on the other side by a thumb screw. The collars are knife-edged on the inside and so formed that diameter through the ends or shoulders was one eighth of an inch less than through the center of the collar. Thus as the cable shrunk with stretching the apparatus simply fitted itself more firmly onto it due to the pressure of the spring and the compound curvature. Two small hooks were placed upon the outside of the collars at opposite ends of a diameter from which scales, graduated to .01 of an inch and which could easily be read to .001 of an inch, were suspended. Two transits as shown in Plate No. VI, were set up, one to read the upper scales and one to read the lower, the distances between collars being in all cases about three feet.

PLATE NO.7

*Scale Holder*

- 1- Collar 2- Shoulder
3- Thumb-screw 4- Scale Hooks
 5- Spring

PLATE NO. 8



Deflection Apparatus

1- Scale Holder 2- Scales

By carefully leveling the transits they could be turned enough to read both sides, that is, the scales, without bringing in any error and also allowed the two scales to be read while the apparatus turned through a considerable angle.

Then the average of the two top scale readings subtracted from the average of the two bottom scale readings gave the extension over the distance between supports. This distance was determined by measuring with a tape the distance between scale zeros at the beginning of the test and to this adding the average top scale ^{zero} reading and subtracting the average bottom ^{zero} scale reading. This method was incorrect as it gave the distance between the lines of sight of the transits rather than the cable length over which the elongation took place. Upon revising one of the calculations to eliminate this error it was found that the correction was inappreciable due to the fact that the zero readings were always made to coincide as closely as possible with the scale zeros. Then knowing the total extension and the distance over which it occurred, the unit deformations were obtained. In case the scales twisted so far that it became impossible to read them, the load was held constant while they were readjusted and a new zero taken. These deformation ordinates added to the last one of those referred to the

previous zero gave results which were plotted in a continuous curve against the unit loads found from the gage loads and actual area of metal cables as determined from the wire tests.

The first two specimens were tested mainly to try out the alloys, judged from previous work to be the most satisfactory. Since all the alloys tried, held firmly, none showing a slippage of more than one eighth of an inch, these specimens furnished additional data as to cable efficiency and as to the action of a wire rope under load. The readings in the cases of these two specimens, Nos. 1 and 2, were taken as quickly as possible after the increment of load was applied, while with No. 3, No. 4, and No. 5 the load was held constant until the bottom scale, which showed the largest deformation, ceased to move perceptibly, and then the readings taken. This accounts for the steeper slopes of the curves for No. 1 and No. 2 than of the curves for Nos. 3, 4, and 5.

While in every case the socket seemed to show no signs whatever of failure, still it would almost seem that it failed to distribute the strain evenly, since, in each cable tested, three strands broke and three held. (Plate No. IX) Tending to disprove this, however, is the fact that in each of the unbroken strands there was always one or more broken wires. Thus the explanation of

PLATE NO.9*Cable Failures**2, 3, 4 and 5 - No. of Specimen*

this interesting observation is very uncertain and might turn out to be a peculiarity of winding. The ropes tested all broke near enough the center of the specimen to avoid the suspicion that the alloys, even in the case of the very hot aluminum-zinc compounds, in any way decreased the strength of the wires by drawing the temper.

One specimen (No. 2), after the first three strands were broken was further pulled. The remaining strands broke one at a time, but each seemed to be firmly fastened by the babbit metal, as no signs of failure or excessive slippage were noticable.

The following curves, plotted between unit loads, based on actual metal area, and unit deformations show graphically the action of a cable under load. Nos. 1, 2, 3, and 4 are taken from steel specimens cut from rope No.9. (See wire tests, for makeup of rope and size and strength of wires.) No.5 is taken from an iron specimen cut from rope No.6, and shows very much greater ductility and weakness than the steel specimens. Values taken at the breaking of the first wires, show that the iron cable developed only 53.8% of the stress of the steel, while at these stresses the elongation of the iron was 3.5 times that of the steel rope. This would make the iron cable nearly seven times as ductile as the steel. No. 2 was placed in the

machine and sustained the weight of the head for a day before testing which may account for the very slight extension due to the first increment of load. No. 3 was likewise left several days in the machine and, in addition, while being placed in the machine received a load equal to about one fourth of breaking value. This load was thrown off immediately but still this may have removed the initial slack from the cable before the test started, causing almost a straight line variation of stress to deformation. This straight line rightly continues to the ultimate since the ultimate and elastic limit of this material come at very nearly the same point. The first point being off of the straight line is due no doubt to taking up initial slack as the cable was loosened before the test was started. It may be noted that on Curve No. 5 the excessive deformation begins about at the point determined as the elastic limit of the material in the wire tests.

The following table and general data will serve as a supplement to the curves and show the ratio of the actual developed strength of the wire rope to that computed from the strengths of the individual wires.

The first four specimens were from the same rope (No.9), and were composed of steel wires wound into six strands of nineteen wires each. Each strand contained six wires

Figure 1.

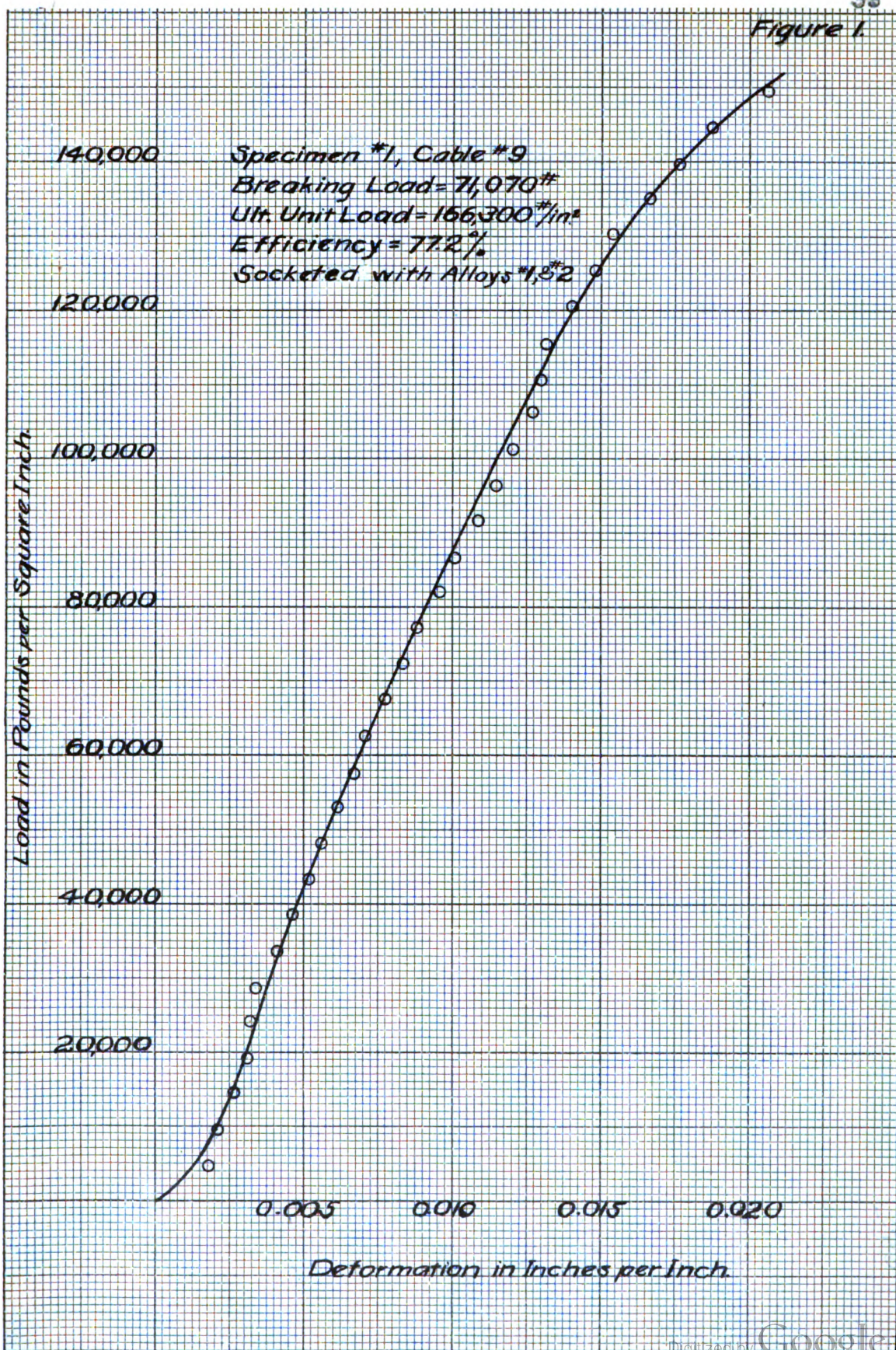


Figure 2.

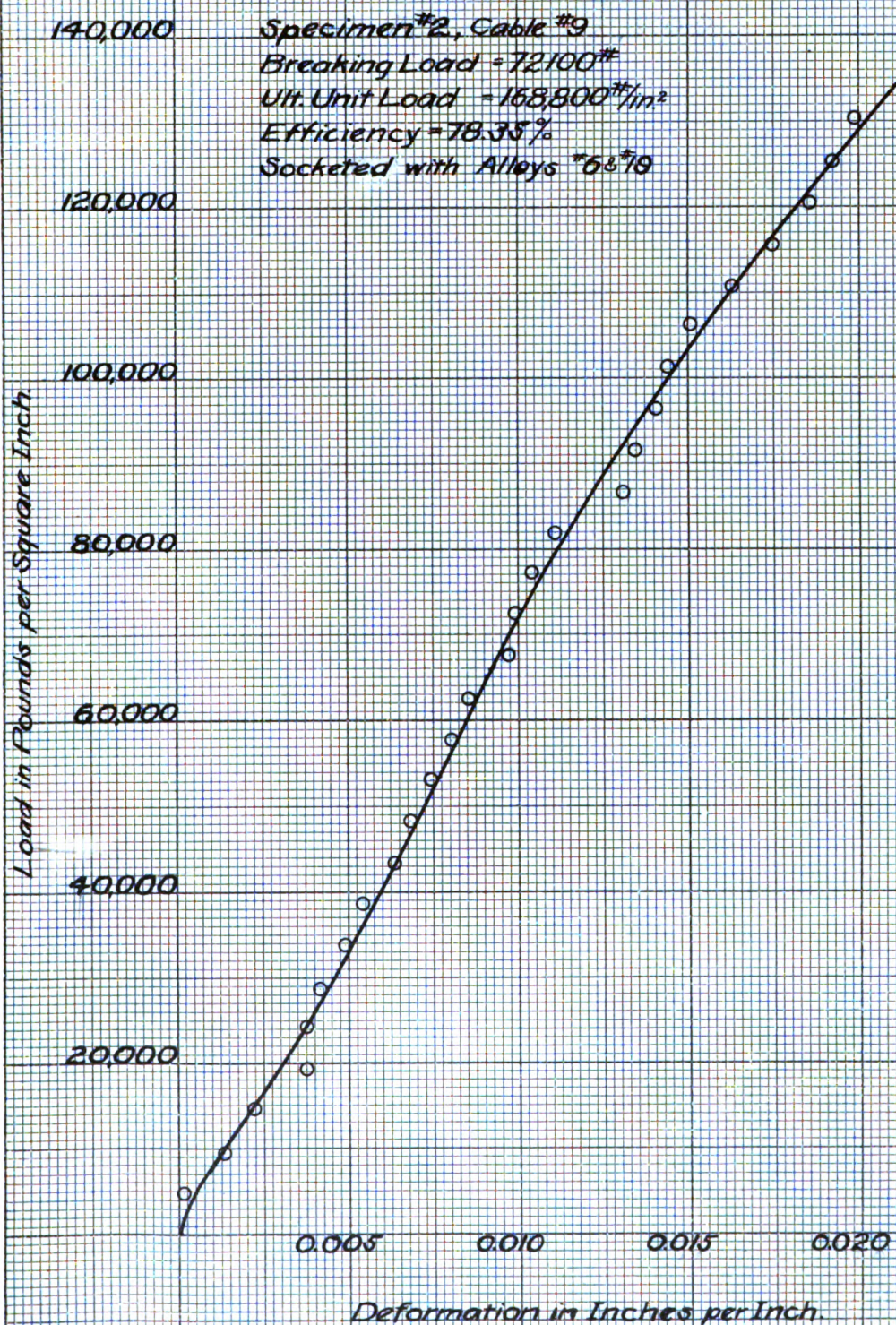


Figure 3.

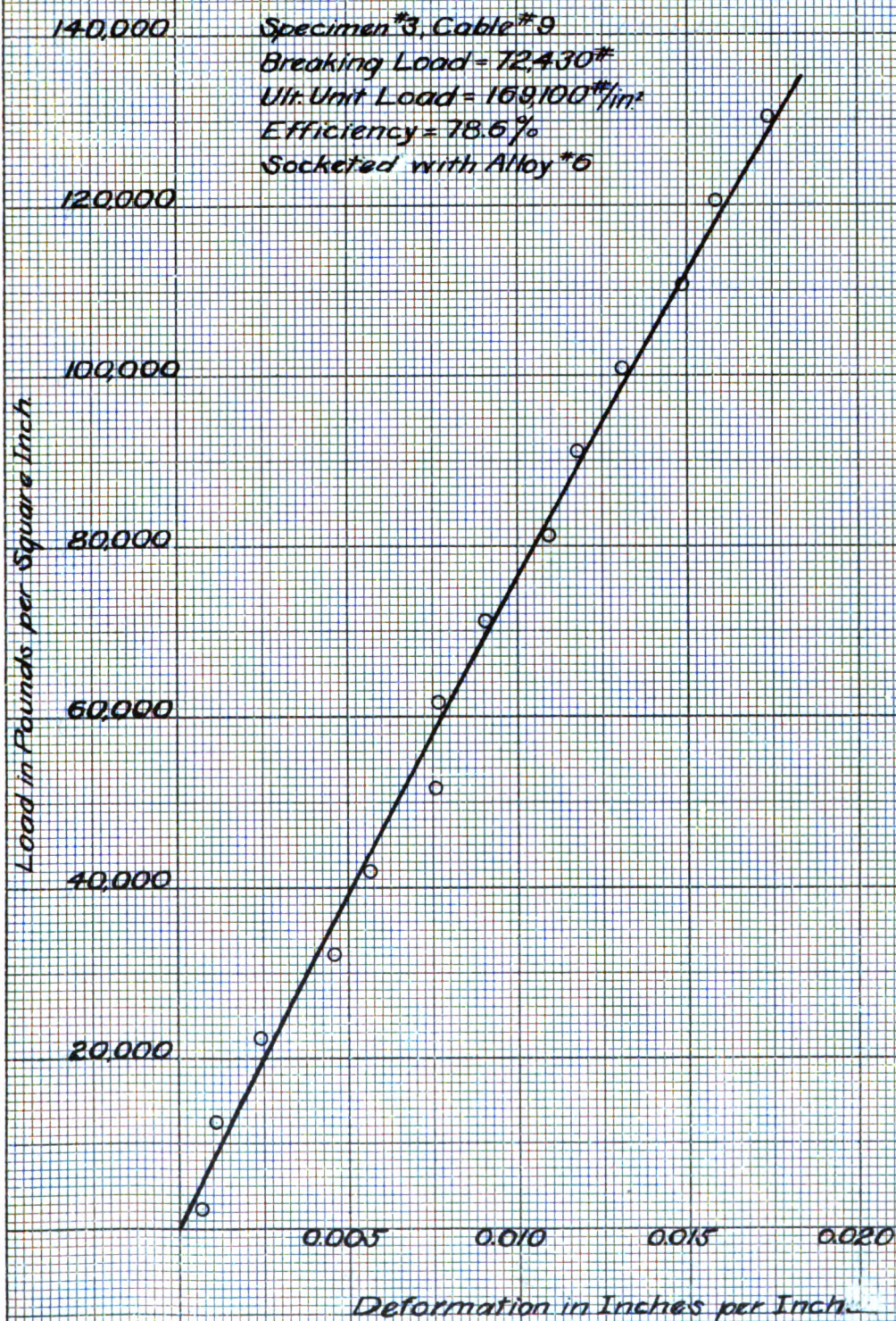


Figure 4.

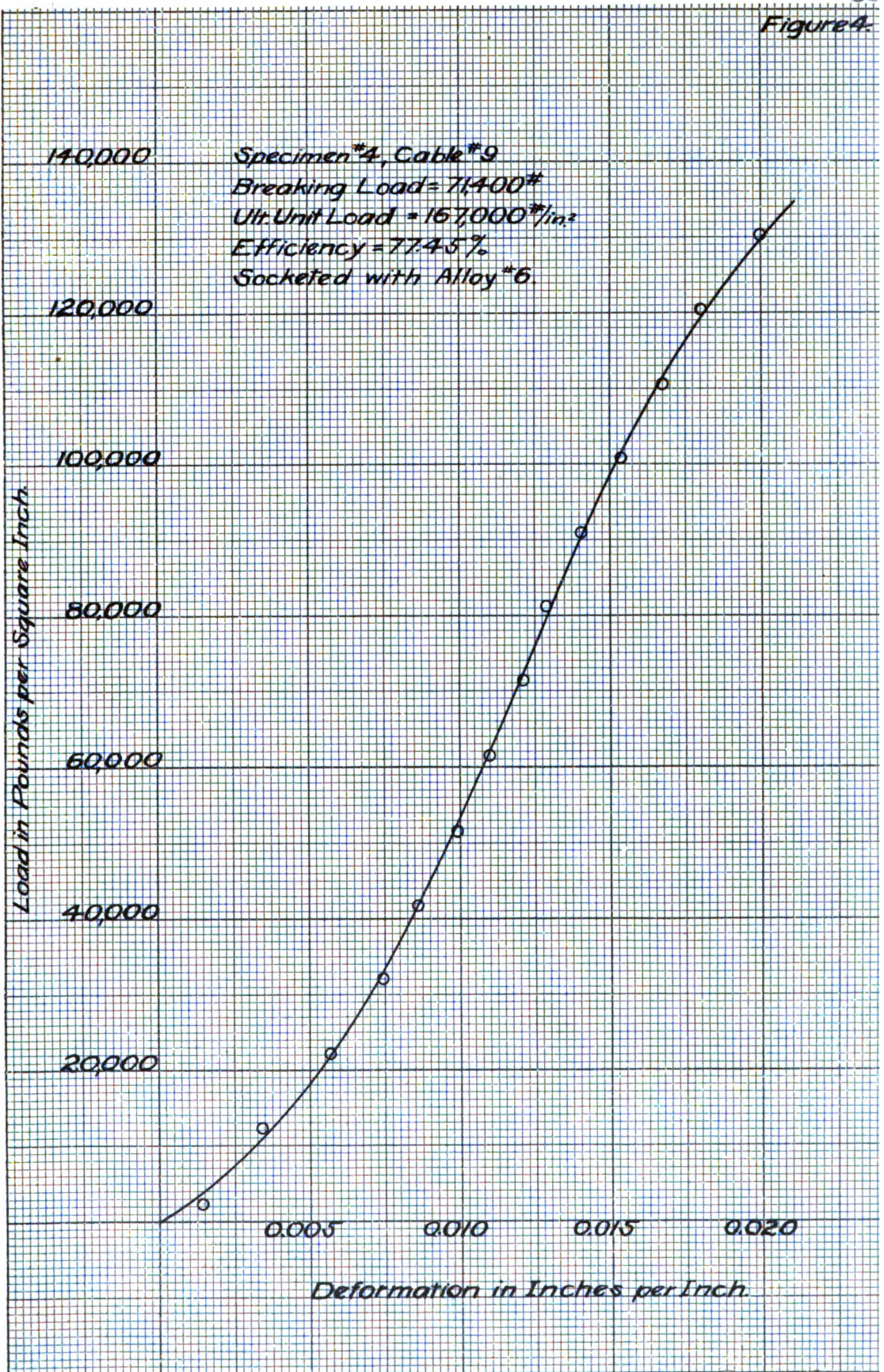


Figure 5.

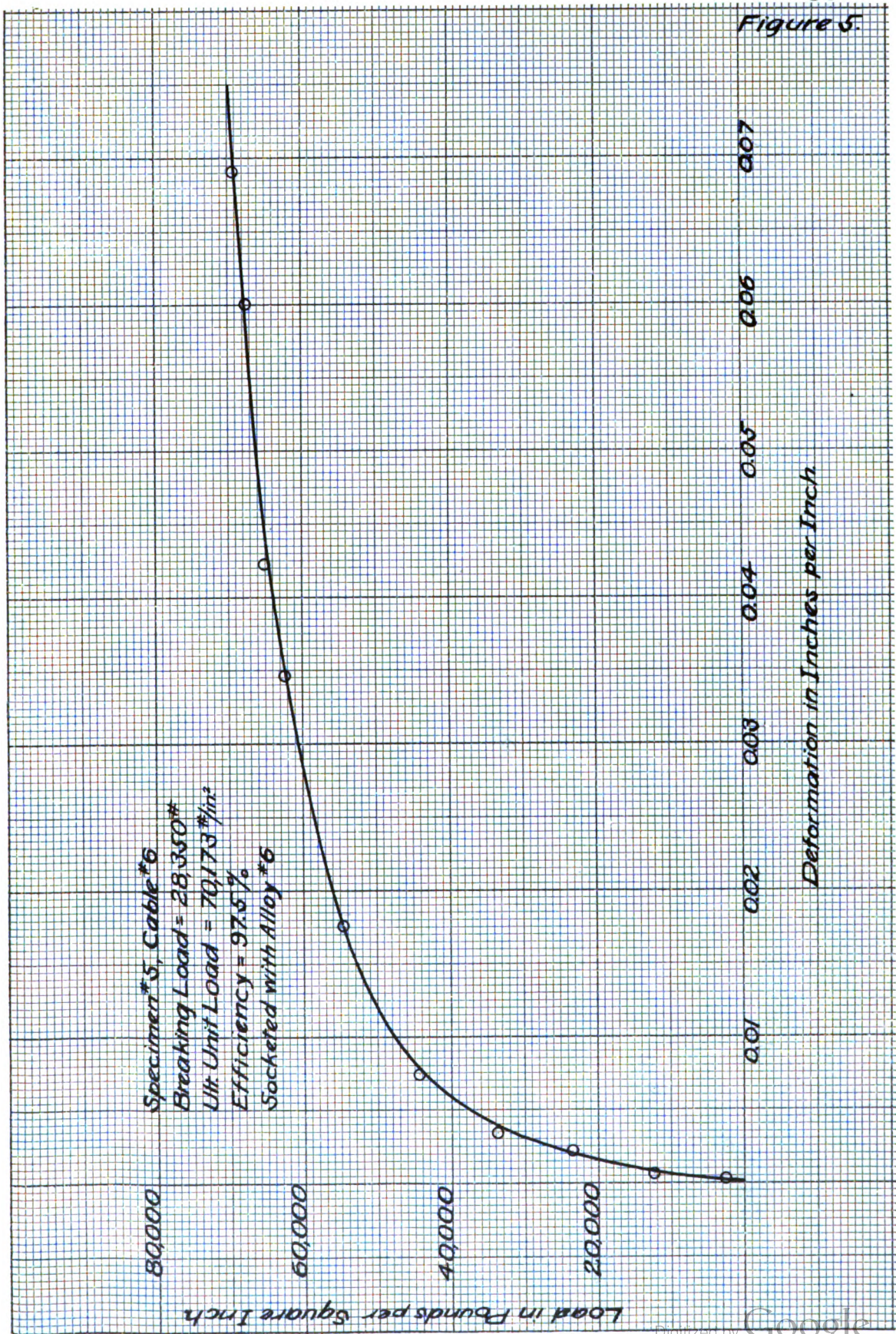
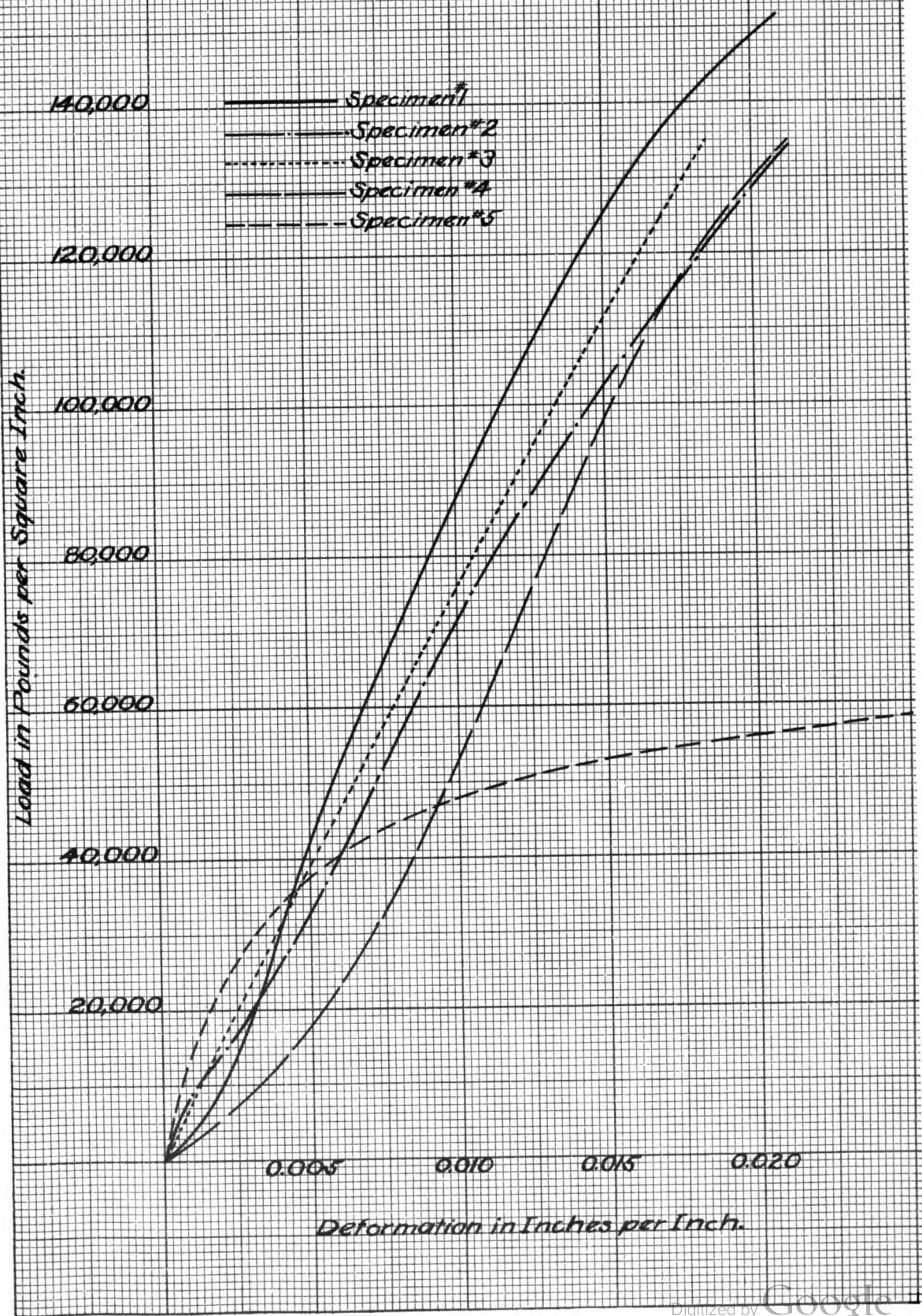


Figure 6.



with diameter equal to .0553 inch and thirteen wires with diameter equal to .0744 inch. The fifth specimen was composed of iron wires, (Rope No.6), wound into six strands of nineteen wires each, all wires being of the same diameter, .067 of an inch. All ropes both iron and steel, were one inch in diameter with a three-eighths inch hemp core.

Table No. 3.

Specimen	Total breaking load in pounds.	Computed.	Efficiency Ratio 2/5
1	71,070	92,120	77.2 %
2	72,100	92,120	78.35 %
3	72,430	92,120	78.6 %
4	71,400	92,120	77.45 %
5	28,350	29,050	97.5 %

While the above results are too few to establish any facts, still it is of interest to note the wide difference in efficiency between the steel and iron ropes, the steel averaging 77.9 % while the iron is 97.5 %. This is probably due to the fact that the iron wires have much greater stability as to molecular structure than the steel. In order to make steel develop such high stress it must be highly tempered and this renders it very susceptible to injury from very slight causes such as bending. Thus it may come about that when these highly tempered steel wires are stressed in a twisted condition, as they are in a cable, they undergo some slight molecular change which weakens them, or it may be, that, owing to their lack of ductility, the steel wires cannot adjust themselves so

that an even distribution of strain is produced. Such an adjustment could more easily take place in the case of the very ductile iron wires. Neither of these weakening effects would come into the straight tension tests of the individual wires and hence this may explain the low efficiency of the steel wire ropes.

The results obtained in these tests would show that it is possible to hold cables with sockets and babbitt metal if the work is done carefully but due to insufficient data it is impossible to conclude as to the equality of the distribution of strain in all the strands and wires, or as to the actual efficiency of various ropes, though it would seem that the iron ropes could be depended upon for a higher efficiency than the hard steel ropes. However these tests open the way for more extensive research along these general lines where ropes of different sizes and different makeup of strands and different lays and grades of materials could be used and their relative advantages and disadvantages determined. It would also be interesting to investigate the effect of the length of specimen and size and shape of the sockets upon the strengths of the various wire ropes.

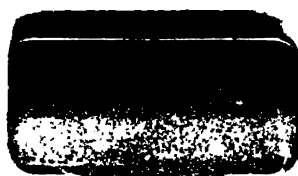
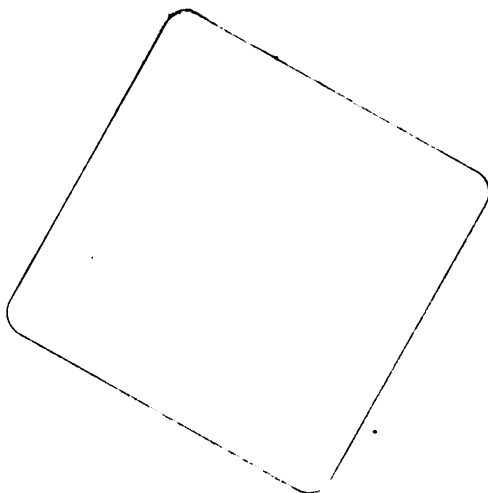
Approved

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